GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station

PROJECT TERMINATION

Date November 15, 1967

PROJECT TITLE: Air Cleaning by High Speed Inertial Impaction

PROJECT NO: B-278

PROJECT DIRECTOR: Clyde Orr, Jr.

SPONSOR: Public Health Service

TERMINATION EFFECTIVE: 9-30-67

CHARGES SHOULD CLEAR ACCOUNTING BY: 11-30-67

Project expired September 30, 1967. Any charges incurred after this date are not allowable and must be transferred from the project.

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REPORTS 300, B-278

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GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

FINAL REPORT

PROJECT B-278

AIR CLEANING BY HIGH-SPEED INERTIAL IMPACTION

By

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RESEARCH GRANT AP-00373

1 OCTOBER 1964 through 30 SEPTEMBER 1967

Prepared for
DIVISION OF AIR POLLUTION
BUREAU OF STATE SERVICES
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
WASHINGTON, D.C.

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I. SUMMARY

Laboratory and pilot-plant scale wet scrubbers which utilize spinning disk atomizers to achieve fine droplet sizes and high relative velocities between particles and droplets were evaluated. These devices were found to be considerably more efficient than scrubbers of conventional design, particularly in the particle size range from one to ten microns in diameter. Water-air ratios required were only about one-fifth of those normally used. The collection efficiency of the pilot-plant scale scrubber was found to be relatively insensitive to particle loadings from about one to twenty grains per standard cubic foot. The surface tension of the scrubbing liquid had only a slight effect on collection efficiency. Rotor speed was the most sensitive operating variable, higher speeds giving better collection efficiencies. For a wide range of operating conditions, the static pressure drop across the pilot-plant scale scrubber varied from 1/4 to 1/2 inch, water gage.

Power requirements, in terms of contacting power, were comparable or slightly higher than for conventional scrubbers. A shortage of time and funds prevented detailed economic and optimization studies; however, it is believed that operating costs could be reduced well below that of conventional scrubbers of comparable efficiency. Since the design of spinning disk scrubbers permit their being mounted directly in existing ducts or stacks, initial capital outlay should be relatively small.

Follow-up studies are needed to optimize operating conditions and to study the feasibility of simultaneous absorption of gaseous pollutants such as sulfur dioxide in the scrubbing liquid.

II. INTRODUCTION

A. Background

There are five basic types of devices used to remove dust particles from a gas stream. They are: settling chambers, cyclones, scrubbers, bag filters, and electrostatic precipitators. The latter three are mainly used when collection efficiencies of above 90 per cent are desired.

Several types of high energy scrubbers have been used to effect high collection efficiencies. However, most scrubbers show a rapid decrease in efficiency when the particle size drops below about 10 microns in diameter. The primary reason for this decrease in efficiency is the low relative velocities between droplets and these smaller particles with a resultant lowering of the number of particle-droplet collisions. A high degree of liquid atomization and large relative velocities between droplets and particles must be realized if high scrubbing efficiencies are to result. Conventional scrubbers usually attempt to achieve these requirements by atomization of the scrubbing liquid at high pressures in a direction opposite to the flowing gas-particle stream. The purpose of this study was to explore several novel methods for achieving these basic requirements for inertial impaction and, hopefully, to design a high efficiency scrubber with distinct advantages over the present state-of-the-art designs.

Spinning disk atomizers have been shown (1,2) to be highly effective

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1/ C. R. Adler and W. R. Marshall, Jr., "Performance of Spinning Disk Atomizers - Part I," Chem. Eng. Progress 47, No. 10, 515-522 (October 1951).

2/ C. R. Adler and W. R. Marshall, Jr., "Performance of Spinning Disk Atomizers - Part II," Chem. Eng. Progress 47, No. 12, 601-608 (December 1951).

in generating finely divided liquid droplets and in imparting a high radial velocity to the droplets as they leave the disk. This report evaluates several exploratory scrubber designs which achieve high degrees of atomization and high relative velocities between the water droplets and dust particles by placing spinning disk atomizers directly in a flowing gas stream. Such designs also have the advantage of requiring less supporting or infra-structure since they are placed directly in a stack or duct. With this arrangement the water droplets generated move at high velocities in a direction perpendicular to the mean direction of the dirty gas stream until they eventually are collected on the wetted wall of the stack or duct. The first scrubber tested was a laboratory model operated at low gas flow rates and the second was a pilot plant model intended to simulate operating conditions in an industrial stack. In both scrubbers, design details and operating parameters were varied to determine their effect on collection efficiency.

B. Collection mechanisms

Three primary collection mechanisms were included in the design of the two types of scrubbers used in this investigation. One of these is centrifugal force. A centrifugal field is generated when air is entrained by the spinning rotors and by the resulting swirling motion that is imparted to the gas stream. Particles in this gas stream are thus forced outward where they eventually collide with the wetted-wall and are collected. The second collection mechanism is impaction between dust particles and the fine water droplets generated by the spinning disks. The impaction efficiency, N_t, of a water droplet colliding with a dust particle can be approximated by

$$N_t = \frac{D_p^2 \rho_p U}{18\mu D_b} \tag{1}$$

where D_p is the diameter of the particle, ρ_p the density of the particle, U the relative velocity between the particle and water drop, μ the viscosity of the gas stream, and D_b the diameter of the water drop. From the above relation it is apparent that the impaction efficiency increases linearly as the relative velocity between the particle and the water droplet increases. In this investigation a high relative velocity was obtained by producing a plane of high velocity water droplets normal to the direction of particle movement. Equation (1) shows also that the impaction efficiency increases as the diameter of the water droplets decreases, or, conversely, as the degree of atomization of the water increases. A third collection mechanism is the entrainment of particles by the water droplets and subsequent diffusion onto the droplet surfaces. As the droplets move through the gas stream they entrain particles in their wake. These entrained particles are carried with the water droplets toward the collecting surfaces.

C. Droplet formation from a spinning disk atomizer

In a spinning disk atomizer, liquid is fed onto the center of a rotating plate and spreads as a thin film to the periphery. The break-up of this liquid is complex and rigorous theoretical relationships expressing the droplet-size distribution from the disk have not been formulated. Also, the complex interaction of the spray from the disk with air currents surrounding the disk make theoretical analyses of the droplet trajectories from the disk virtually impossible. The precise manner in which droplets are produced depends on a number of factors, some of the more important being disk diameter and rotational velocity, liquid surface and interfacial tensions, viscosity, density, and the liquid flow rate. For the condition that the liquid leaves a disk surface with a tangential velocity essentially equal to the peripheral velocity of the disk, Putnam, et al. (3), developed a dimensional relationship for the mean droplet size (d) of the spray:

$$d = 6.855\ D\left(\frac{\mu_L}{\rho_L \sigma D}\right)^{0.041}\left(\frac{\omega^2 D^3 \rho_L}{\mu}\right)^{-0.522} \qquad (2)$$

where D is disk diameter in cm., ω the angular velocity in radians/sec., ρ_L the liquid density in cm^3, σ the liquid interfacial tension in dyne/cm., and μ_L the viscosity of the liquid in poise.

From equation (2) the droplet size is seen to be approximately inversely proportional to the rotational speed of the disk. If the liquid to be atomized is water (ρ_L = 1 gm/cm^3, σ = 73 dyne/cm, μ_L = 1 centipoise), an 8-inch disk spinning at 7,000 rpm will generate a spray with a mean droplet diameter of 60 microns, doubling the rotational speed to 14,000 rpm will approximately halve the mean droplet size.

Equation (2) is valid only if the liquid leaves the disk's surface with a tangential velocity essentially equal to the peripheral velocity of the disk. A fairly large disk, a viscous liquid, and a low liquid feeding rate are essential conditions for satisfying the conditions for which

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3/ A. A. Putnam, et al., "Injection and Combustion of Liquid Fuels," Wright Air Development Center, Tech. Report, 56-344 (1957).

equation (2) is valid. An increase in liquid feeding rate increases the average droplet size at constant disk speed. Based on studies of a variety of vaned, cupped, and shrouded disks Friedman, et al. (4), found that the average droplet size varies with the feed rate to the 0.2 power.

D. Atomizing disk design

A literature survey of the many types of spinning disk atomizers revealed no outstanding differences in the droplet-size characteristics of the sprays produced by them. For example, eighteen different disks including variations of the radial-vaned type, curved vane, homogenizing, and bowl and saucer varieties were tested by Adler and Marshall (5) who reported no marked differences in droplet size characteristics of the sprays produced for a single set of conditions by the different designs. Two types of spray disks were used by Wallman and Blyth (6) in a study of spray drying. Their results showed very little difference in the average droplet size produced by the two disks of different design. Large differences were shown to exist, however, in the power requirements of various designs. For example, at 20,000 rpm and 2 pounds of feed liquid per minute, one disk required 1000 watts as compared to 675 watts for the other wheel of the same size at the same speed. An increase in power requirements always resulted when the atomizing disk entrained large quantities of air in addition to accelerating the liquid.

4/ S. J. Friedman, F. A. Gluckert, and W. R. Marshall, "Centrifugal Disk Atomization," Chem. Eng. Progress 48, 181-191 (1952).

5/ C. R. Adler and W. R. Marshall, "Performance of Spinning Disk Atomizers," Chem. Eng. Progress 47, No. 10, 515 (1951).

6/ R. H. Wallman and H. A. Blyth, "Product Control in Bowen-Type Spray Dryer," Ind. and Eng. Chem. 43, No. 6, 1480 (1951).

The type of atomizing disk selected for use in this study has three principal advantages:

1. The simple, flat disk design reduces the rotor weight to a minimum, hence the power requirements are held to a minimum.

2. Liquid is atomized on both the top and the bottom surfaces of the disk. Higher liquid feeding rates can thus be obtained and the chances of particle capture by impingement is improved by the double spray action.

3. At a given liquid feed rate, two thin films of liquid are formed on the disk surfaces rather than the one thicker film formed with a single disk surface. Since the liquid droplet size is proportional to the film thickness, a finer spray is formed.

III. EXPERIMENTAL APPARATUS AND PROCEDURE

A. Phase I - Modified Sharples Centrifuge

The experimental apparatus employed in the first phase of this study was a modified Sharples Super Centrifuge. A schematic diagram of the experimental apparatus is shown in Figure 1. Figure 2 presents an assembly drawing of the modified centrifuge showing the essential features of the rotor and flow patterns within the device. Figure 3 is a photograph of the modified centrifuge shown with the top cover removed to show the rotor and impactors.

For a determination of the particle removal efficiency, the rotor was brought to a predetermined speed and a known flow rate of water was introduced into the bottom of the hollow rotor shaft. The water was atomized through a series of small holes in the hollow shaft at the level of the upper and lower surfaces of the rotor blades and at a series of nozzles located on the rotor shaft approximately half way between the aerosol inlet and the rotor blade surface. An aerosol was generated externally and directed into the centrifuge at a point near the bottom of the rotor shaft. A known quantity of powder was aerosolized with a metered stream of dry nitrogen and the total amount that passed through the apparatus was subsequently collected on an absolute filter and weighed. The mass collection efficiencies were determined from the differences in the quantities of powder fed to and passing through the apparatus.

Collection efficiencies were determined as a function of particle size distribution of aerosol, aerosol concentration, volumetric flow rate of aerosol, water flow rate, rotor speed, and rotor blade configuration.

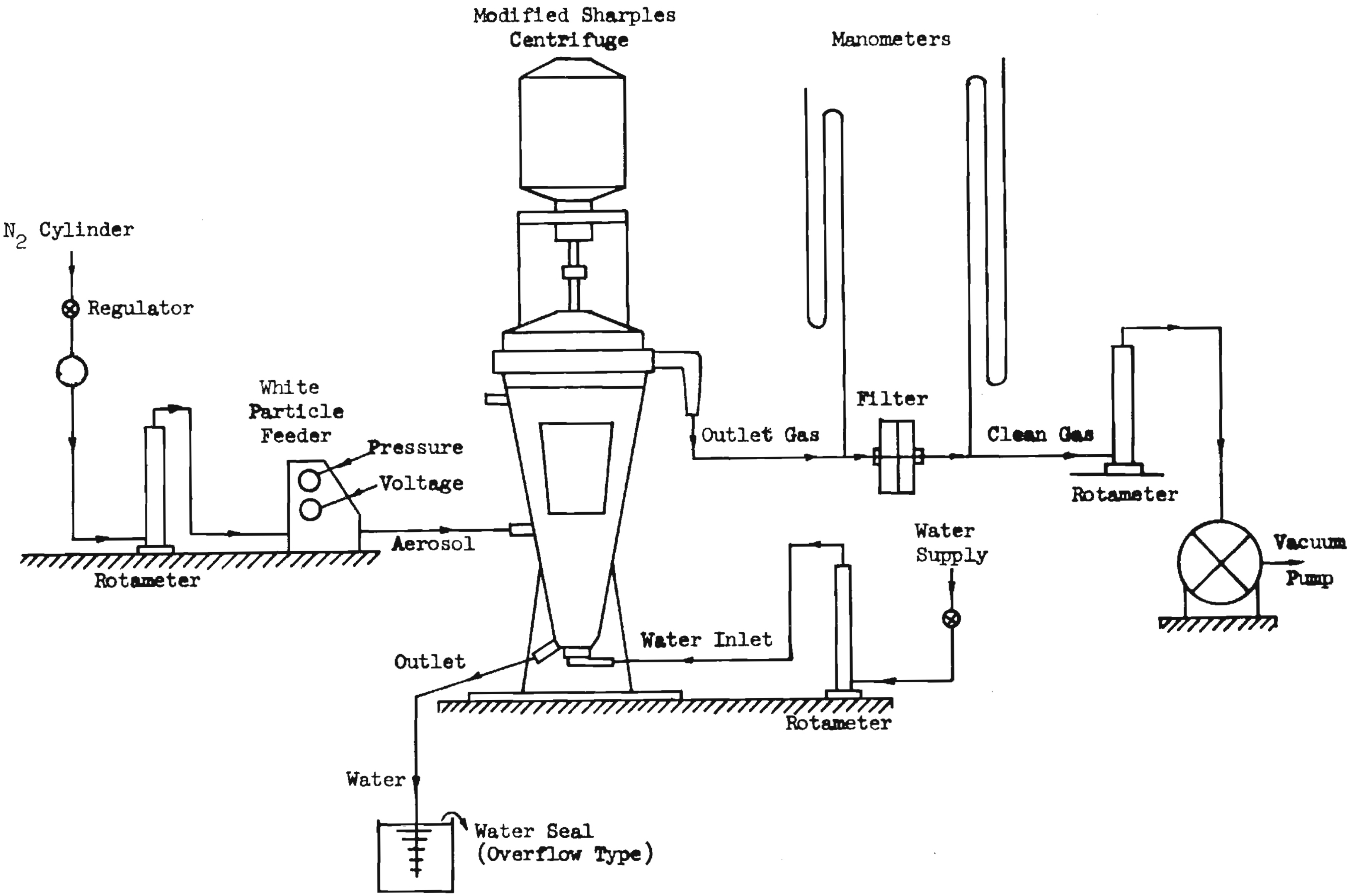


Figure 1. Experimental Setup for Gas Cleaning by High Speed Inertial Impaction.

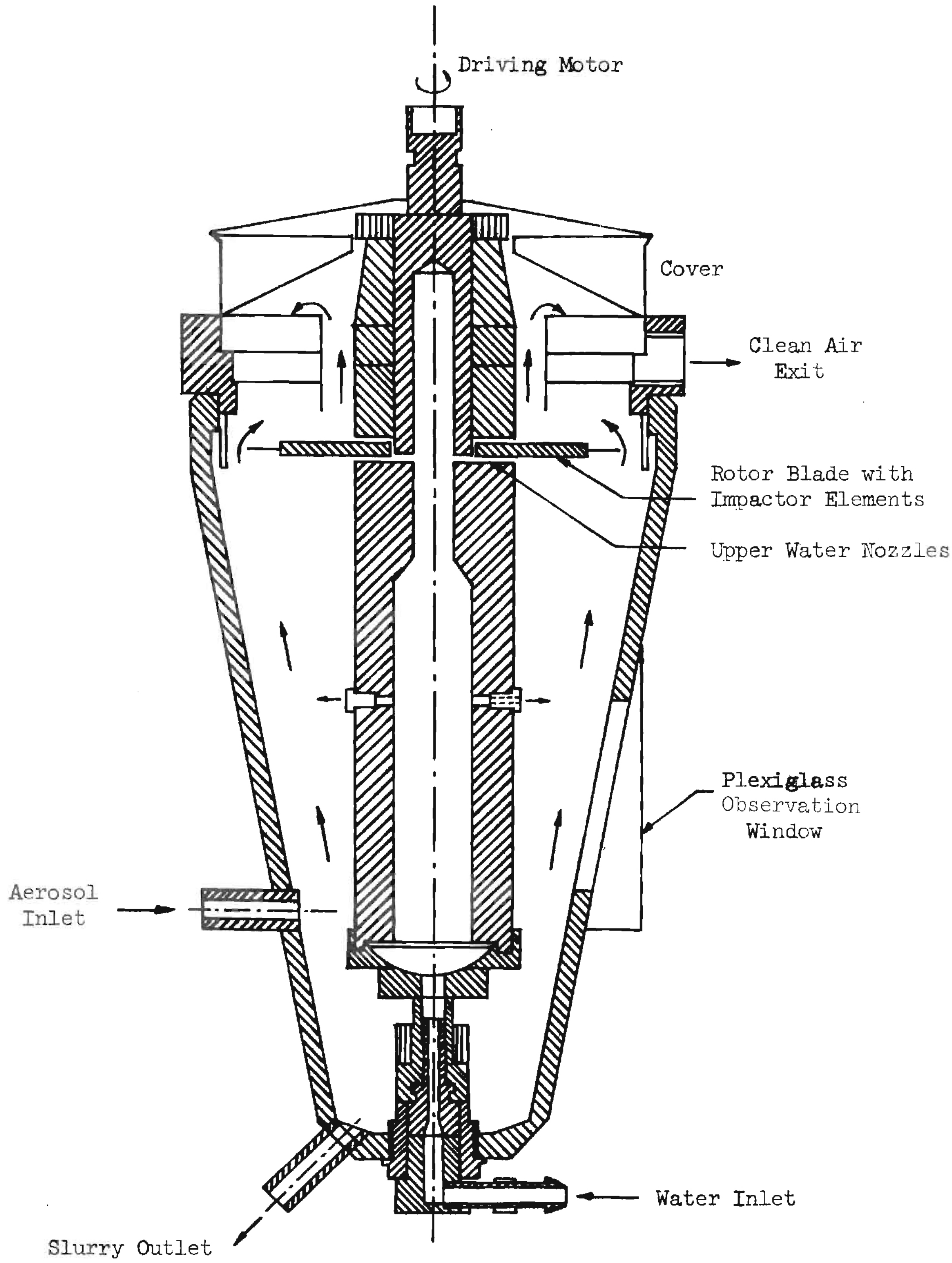


Figure 2. Assembly Drawing of Centrifugal Gas Cleaner Used for High Speed Inertial Impaction Studies.

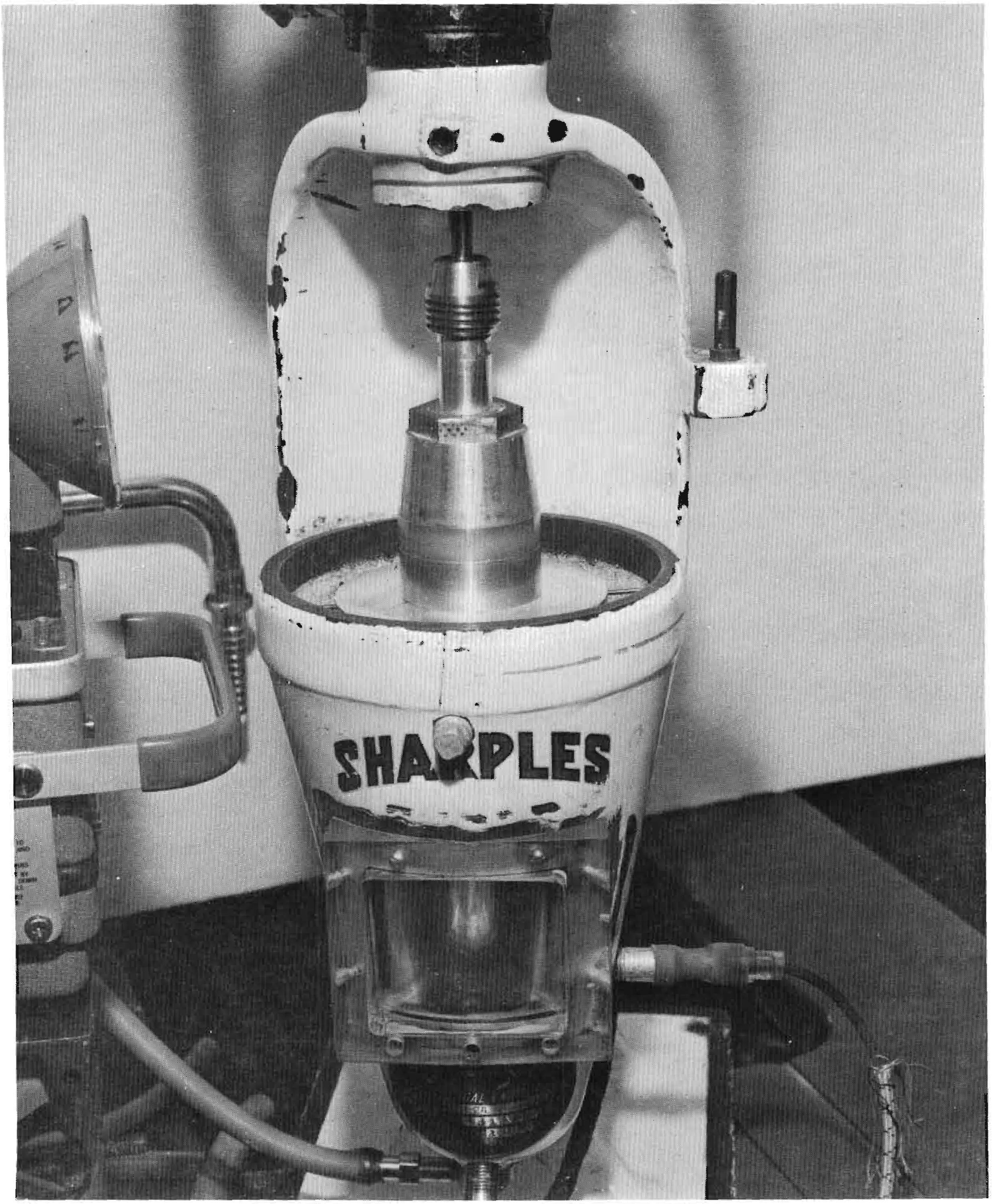


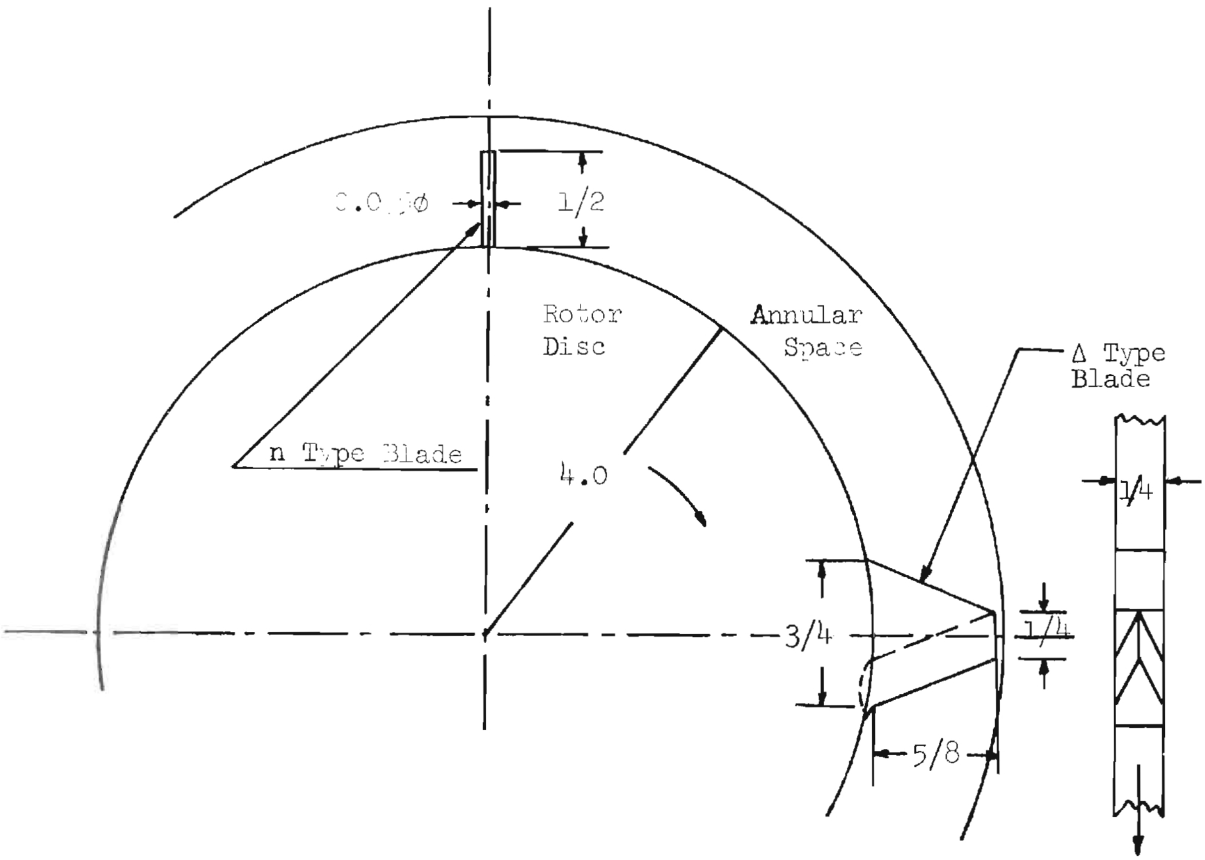
Figure 3. Modified Sharples Centrifuge.

The two types of impactor tips that were used and the three rotor configurations employed in tests are shown in Figure 4. There were positions for four impactors on the rotor periphery and various combinations of the two impactor designs were used during the tests. Figure 5 shows the rotor assembly.

B. Phase II - Simulated industrial stack

The experimental apparatus employed in the second phase of this study consisted essentially of a small transparent, plastic column that was intended to simulate a "typical" industrial stack. The column was constructed of 4 lengths of 12-inch O.D. plexiglass pipe with an overall length of 14 feet. Two high-speed air motors that used flat disks for rotors were placed in the column as is shown schematically in Figure 6. The column was closed at the bottom except for blower and aerosol inlets and a drain line. The feed nozzle of an aerosol generator entered one foot from the base of the column. The two rotors were located five feet and seven feet, respectively, from the base of the column. The aluminum alloy rotor disks used were one-fourth inch thick and of two sizes, eight and ten inches in diameter. Only one rotor was used during some of the tests. A tube that supplied water for atomization from the disk surfaces was located directly above the center of each disk. Two variable speed blowers were connected to the bottom of the stack, thereby permitting a wide variation in the gas volume and velocity through the stack.

The sampling system used to determine the weight of powder leaving the stack is also shown in Figure 6. A baffle, which is not shown in Figure 6, was installed in the stack above the upper rotor to reduce the vortex motion



Rotor Configuration I - Rotor disc with no impactor elements
Rotor Configuration II - Rotor disc with four n-type impactors
Rotor Configuration III - Rotor disc with four Δ-type impactors

Figure 4. Rotor Design and Various Impactor Configurations Used.

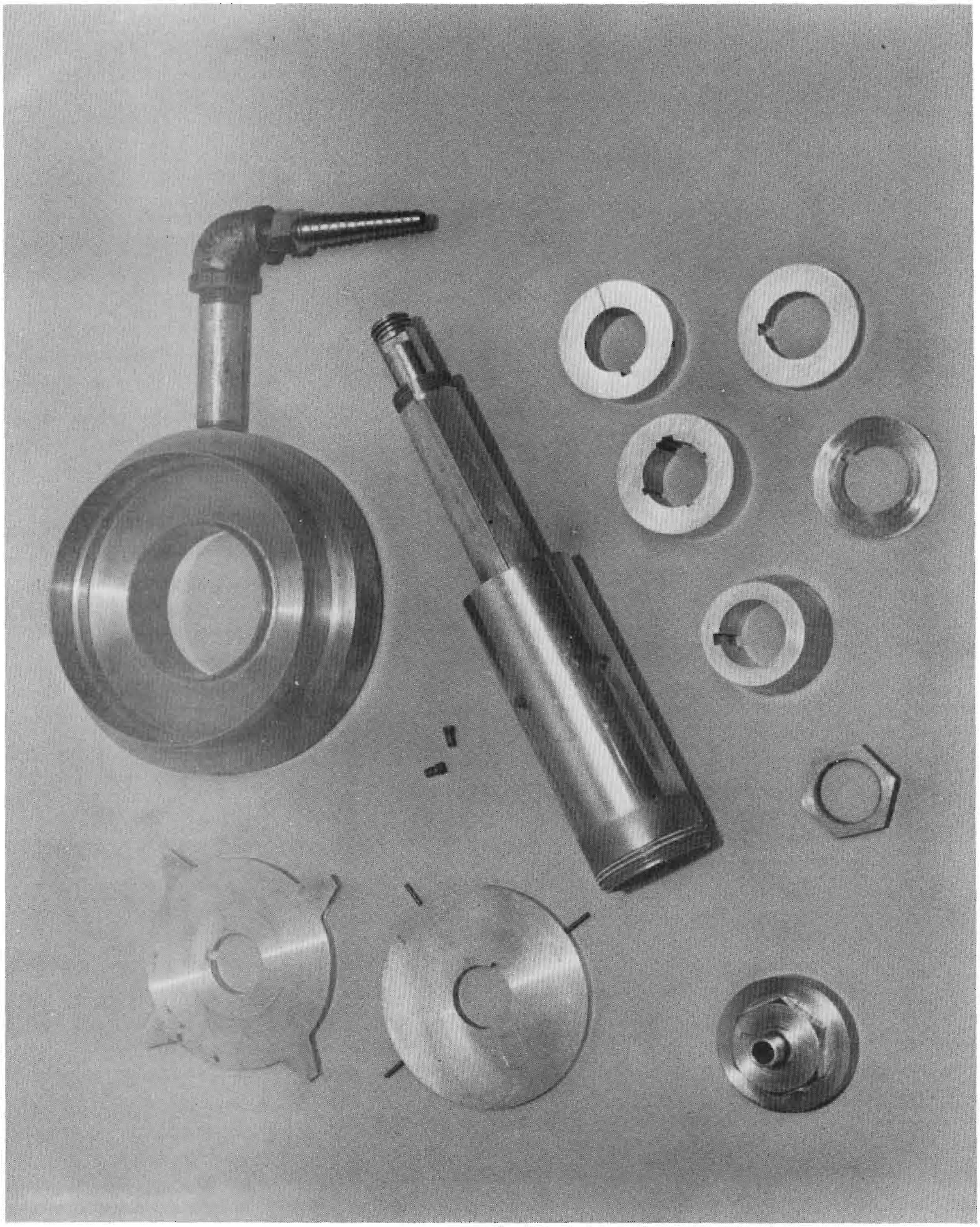


Figure 5. Rotor Components.

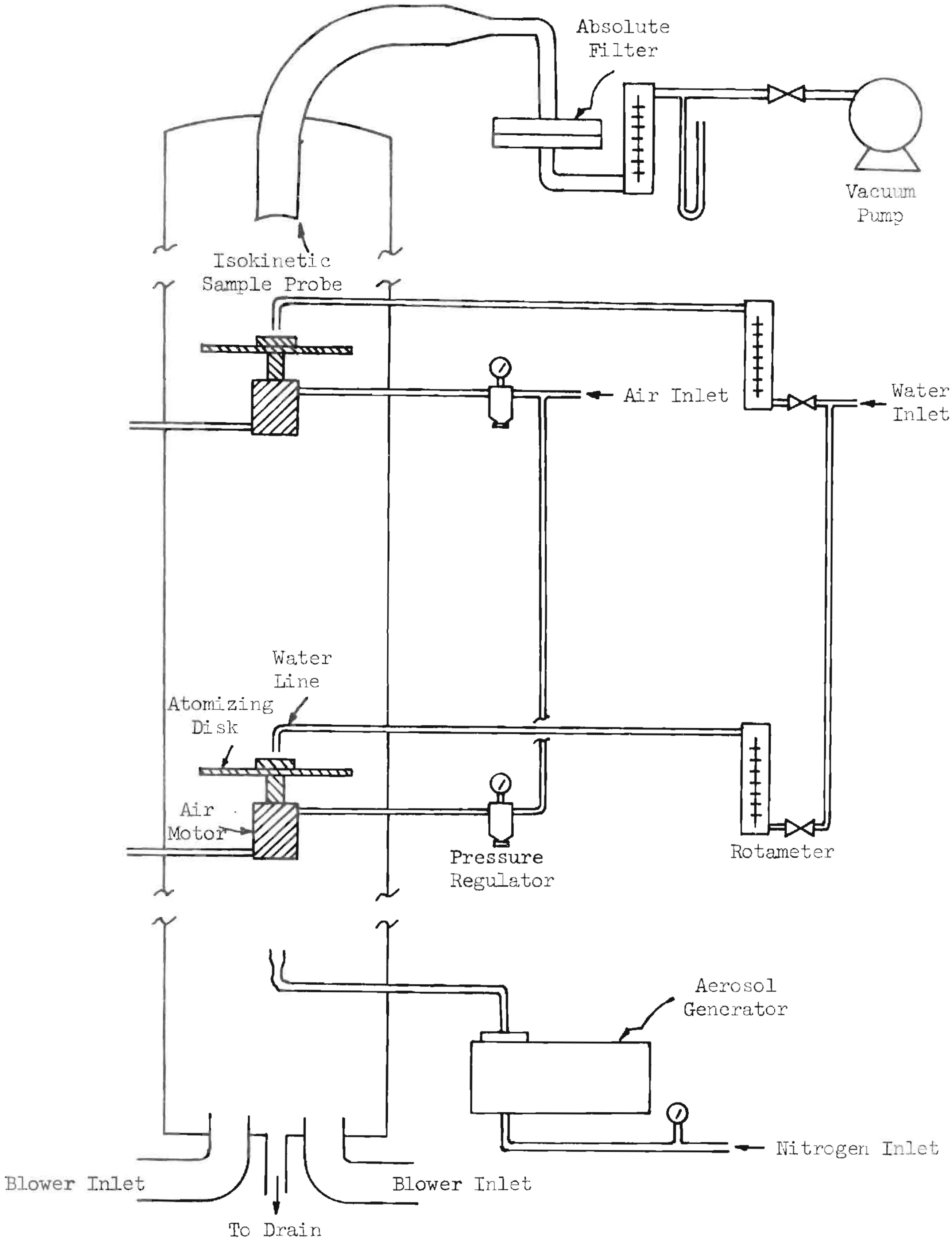


Figure 6. Simulated Industrial Stack Apparatus.

of the air stream and produce a more uniform velocity distribution at the point of sampling. The sampling system consisted of a 2-inch I.D. pipe bent 90° on an eight-inch radius which was used as a sample probe, a 142 mm filter holder and membrane filter (0.45μ pore size), rotameter, manometer, valve, and vacuum pump. The vacuum pump of the sampling apparatus was started just prior to start-up of the aerosol generator and stopped shortly after shut-down of the aerosol generator. The runs were generally from 4 to 30 minutes duration, depending on the volumetric flow rate of the total gas stream entering the stack and the aerosol concentration. The rotors, water flow, and blowers were stabilized at the desired rates before sampling started, and were maintained at these ratings until the sampling system was shut down.

The membrane filter used for sampling was conditioned at $90^{\circ}C$ for 24 hours before its initial and final weights were determined. The sampling nozzle was washed thoroughly after each run to collect particles adhered to the inside of the nozzle. The wash water was filtered on a second membrane filter prepared and conditioned in the same manner. The dry weights of powder on each filter were added to obtain the total dry weight of sample collected. A composite sample thus was collected from the effluent gas stream, and the total amount of uncollected solids was determined by multiplying the dry weight of the sample by the ratio of the total flow out of the stack to the flow through the sampling system. The flow through the sampling system was maintained at isokinetic conditions.

Figure 7 shows the disassembled rotor unit. The air motor used had a maximum no-load speed of 20,000 rpm at 90 psig. With an 8-inch rotor,

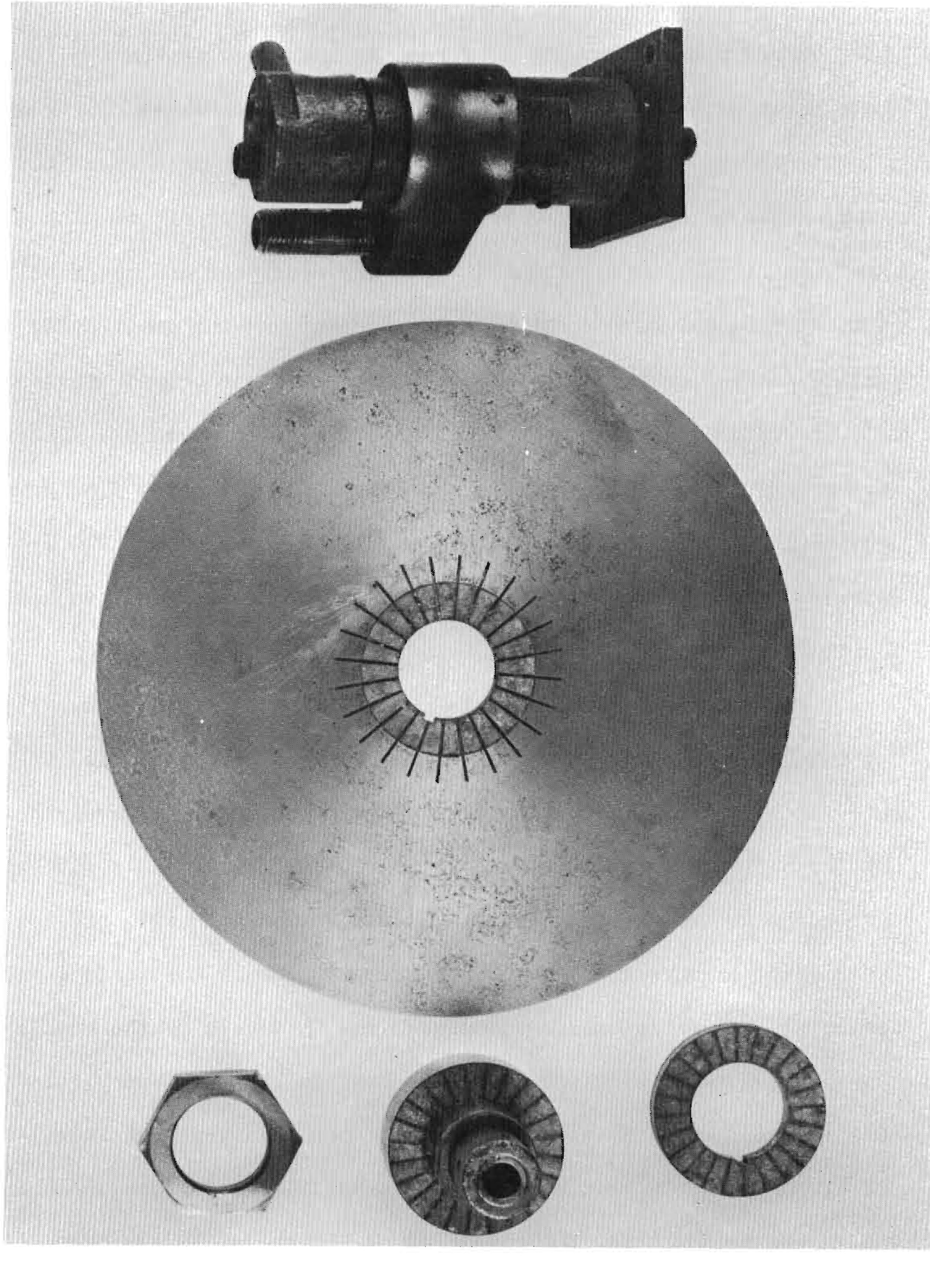


Figure 7. Spinning Disk Atomizer Assembly.

the maximum speed was reduced to 12,000 rpm at 90 psig. The rotor center piece served a dual purpose; it connected the rotor to the shaft, and it distributed water to both the top and the bottom surfaces of the disk. The rotor center piece contains a small water reservoir from which two rows of water outlet holes extend to grooves on the surfaces of the disk. During a run, water was fed continuously into the reservoir and the resulting centrifugal acceleration forced the water through the small holes and into shallow grooves on the surfaces of the disk. Stroboscopic studies showed that the water remained in the grooves for a short distance. However, the centrifugal acceleration and the friction between the flowing water and the disk surfaces finally spread each thread of water into a slightly spiraled, fan-shaped film that remained on the disk surface to the disk periphery where they then broke into small droplets.

The aerosol generator used is shown in Figure 8. The powder to be aerosolized formed a small mound behind a stationary partition in the rotating container. A thin layer of powder was formed between the partition and the bottom of the rotating container. The layer thus formed was carried by the rotating surface under the atomizing nozzle pickups where the powder was entrained by nitrogen flowing across the surface and finally upward through the atomizing nozzles. The thickness of the powder layer was controlled by adjusting the clearance between the stationary retaining partition and the felt-covered bottom of the rotating container. With the nitrogen supply regulated at a constant flow rate, the aerosol density was varied by adjusting the powder layer thickness. Deagglomeration of the entrained powder resulted from the high shear forces generated by flow

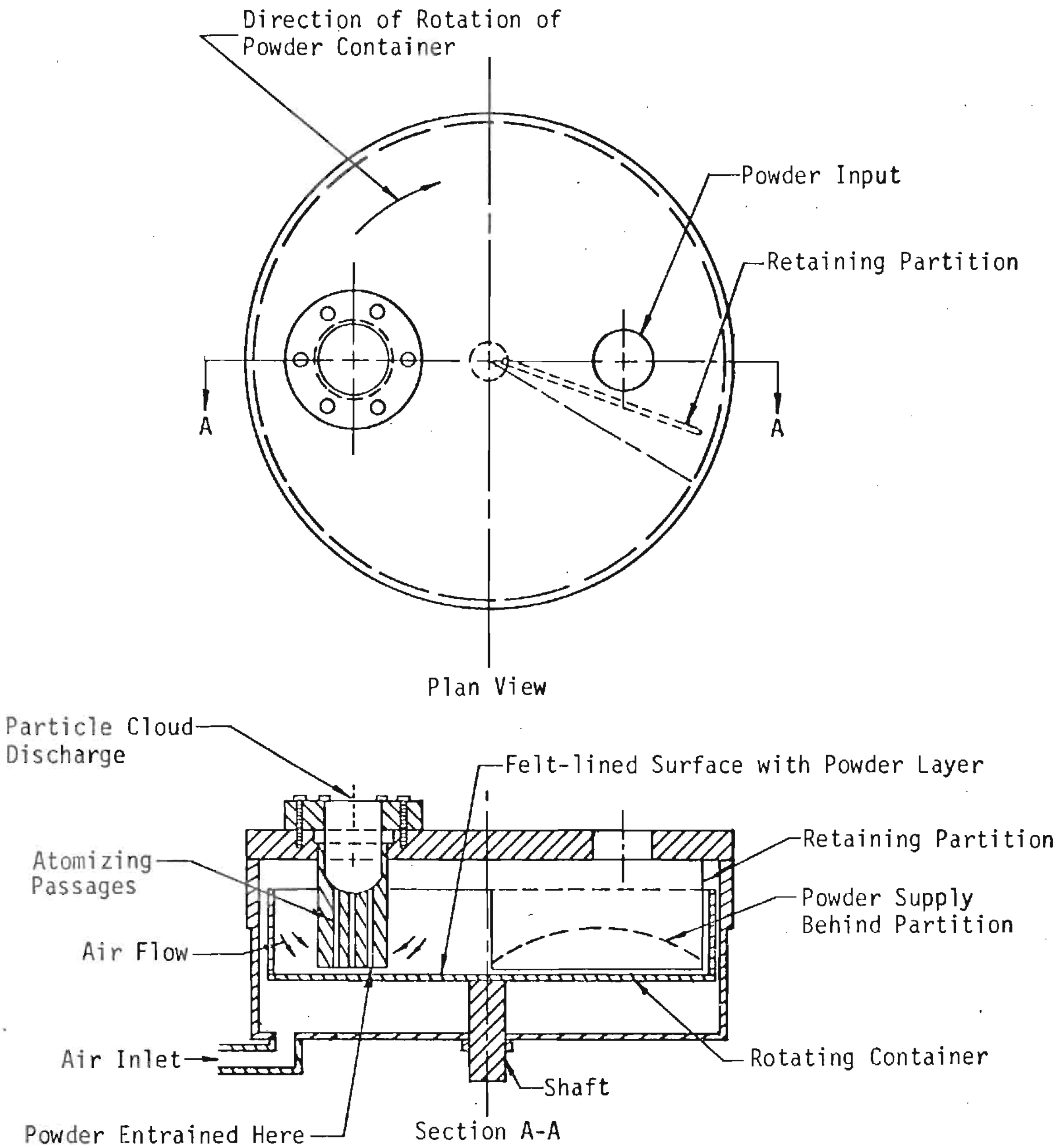


Figure 8. Particle Cloud Generator.

through the small diameter passages. After being atomized, the newly formed particle cloud passed through a length of straight pipe (L/D > 100) to allow the streams from the nozzle to mix thoroughly and to reach a steady flow conditions. The particle cloud was finally directed inside the stack where it was sprayed upward through a conical shaped feeding nozzle.

When the nitrogen flow rate was 20 SCFM, the aerosol flow velocity was sonic, i.e., approximately 1100 feet per second, in the atomizing nozzles. A qualitative test of the degree of deagglomeration achieved was made by passing a microscope slide quickly across the aerosol outlet and examining the deposited particles with a microscope.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

A. Phase I - Modified Sharples Centrifuge

1. Effect of particle size on collection efficiency

Several grades of aluminum oxide powder were used to determine how the particle size distribution of aerosolized powders affects collection efficiency. The size distributions of the samples used were determined with a Coulter Counter. Figure 9 shows the size distributions of a typical feed material, i.e., alumina powder, and of the fraction that escaped from the apparatus and was collected by the sampling system. Figure 10 summarizes the variations of collection efficiency with particle size for aerosols of aluminum oxide.

2. Effect of aerosol concentration

Various concentrations of talc aerosols and of carbon black aerosols were employed to determine how aerosol concentration affects collection efficiency. These two materials were chosen as representative of the largest particle size material--in the case of talc--and the smallest--in the case of carbon black--that are likely to be encountered in most industrial gas cleaning problems. At concentrations greater than about 1 gr/SCF, the collection efficiency varied linearly with concentration for carbon black aerosols as is shown by Figure 11. The collection efficiency shown in Figure 12 for talc aerosols exhibited a linear dependence only when the concentration was greater than about 2 gr/SCF.

3. Effect of water-air ratio

Figure 13 illustrates the variation in efficiency as the water-air ratio increases. The reasons for existence of maxima and minima in the

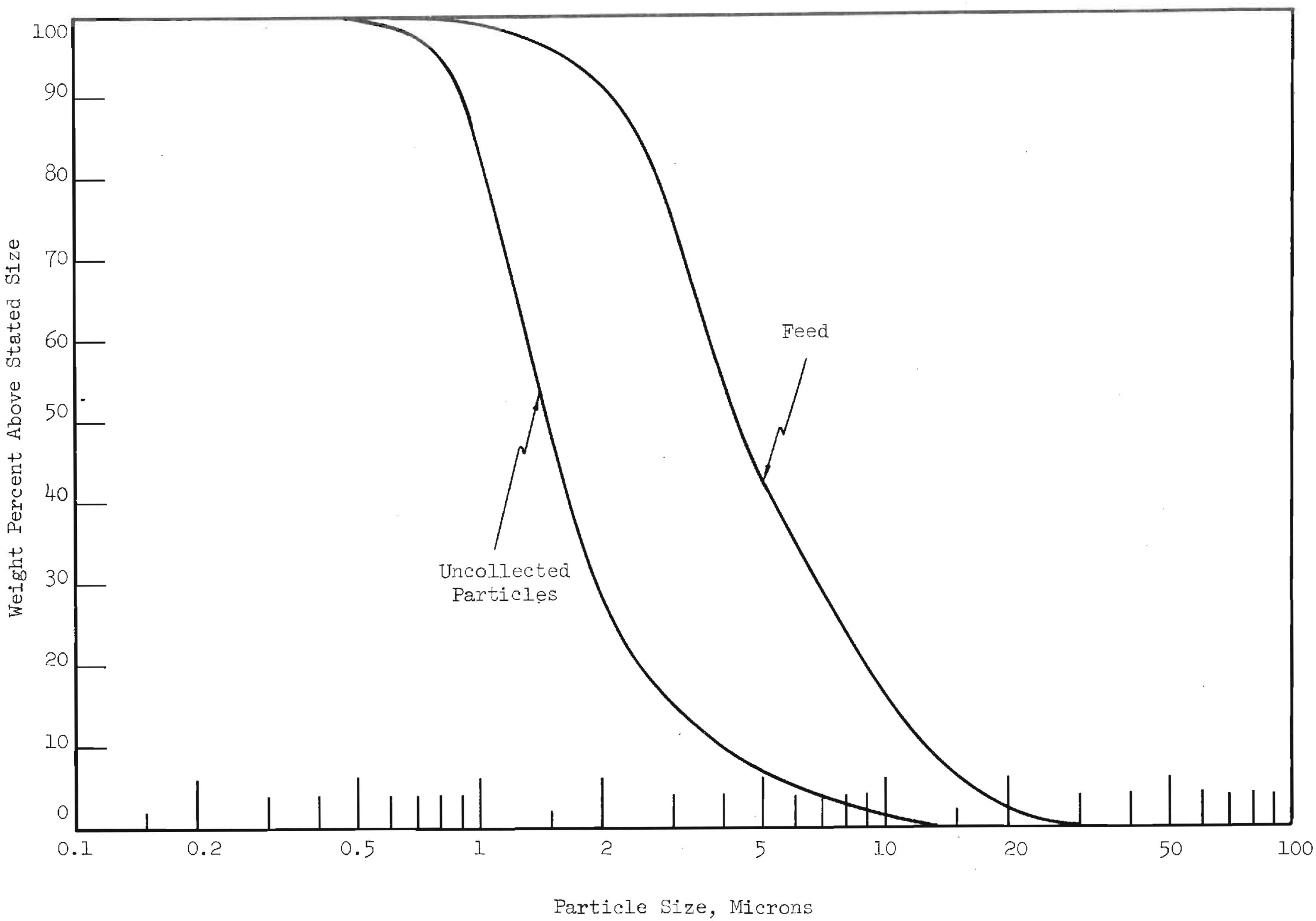


Figure 9. Particle Size Distributions of a Typical Powder Introduced to the Modified Sharples Centrifuge and the Escaping Fraction.

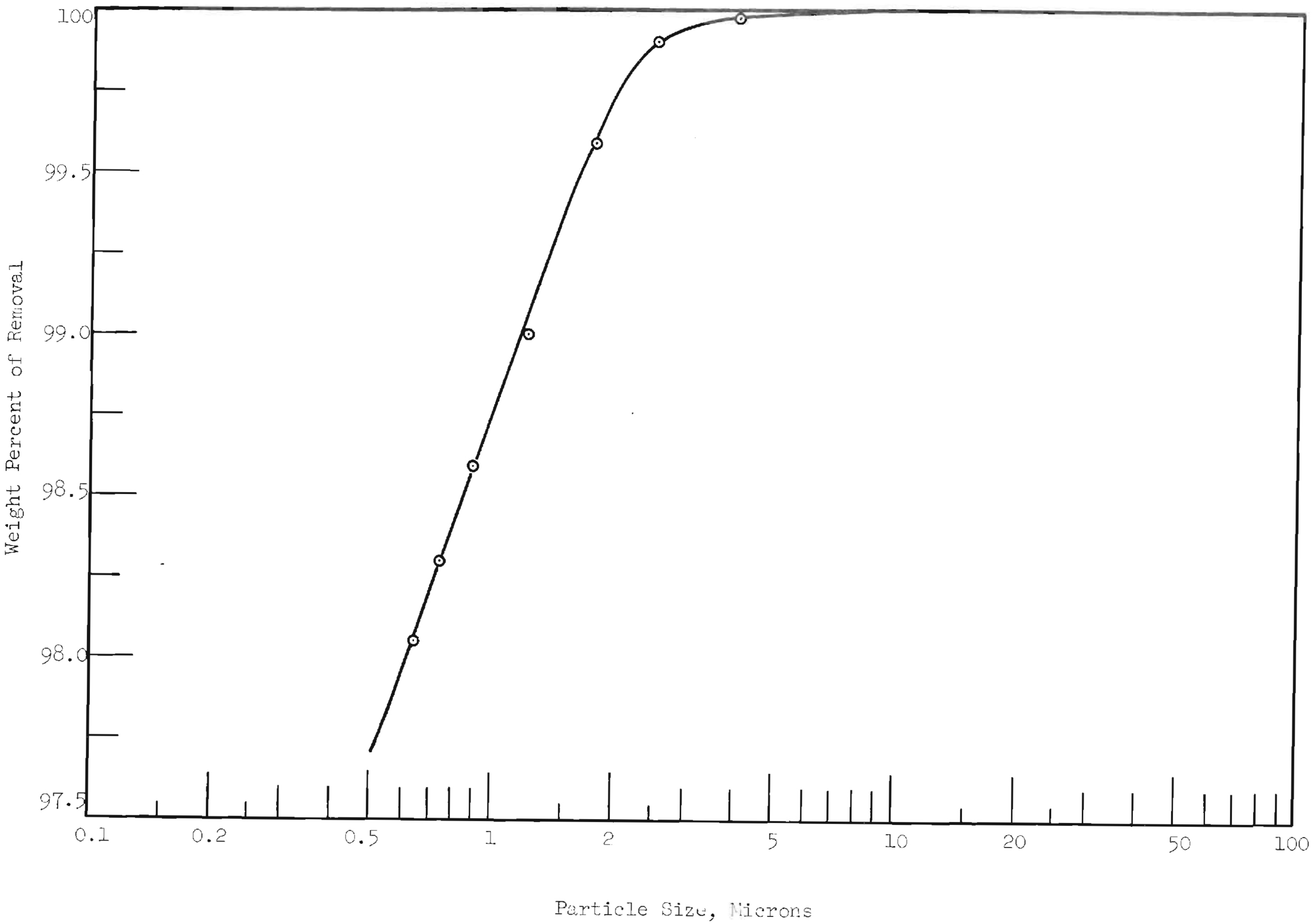


Figure 10. Efficiency of Removal of Aluminum Oxide Powders.

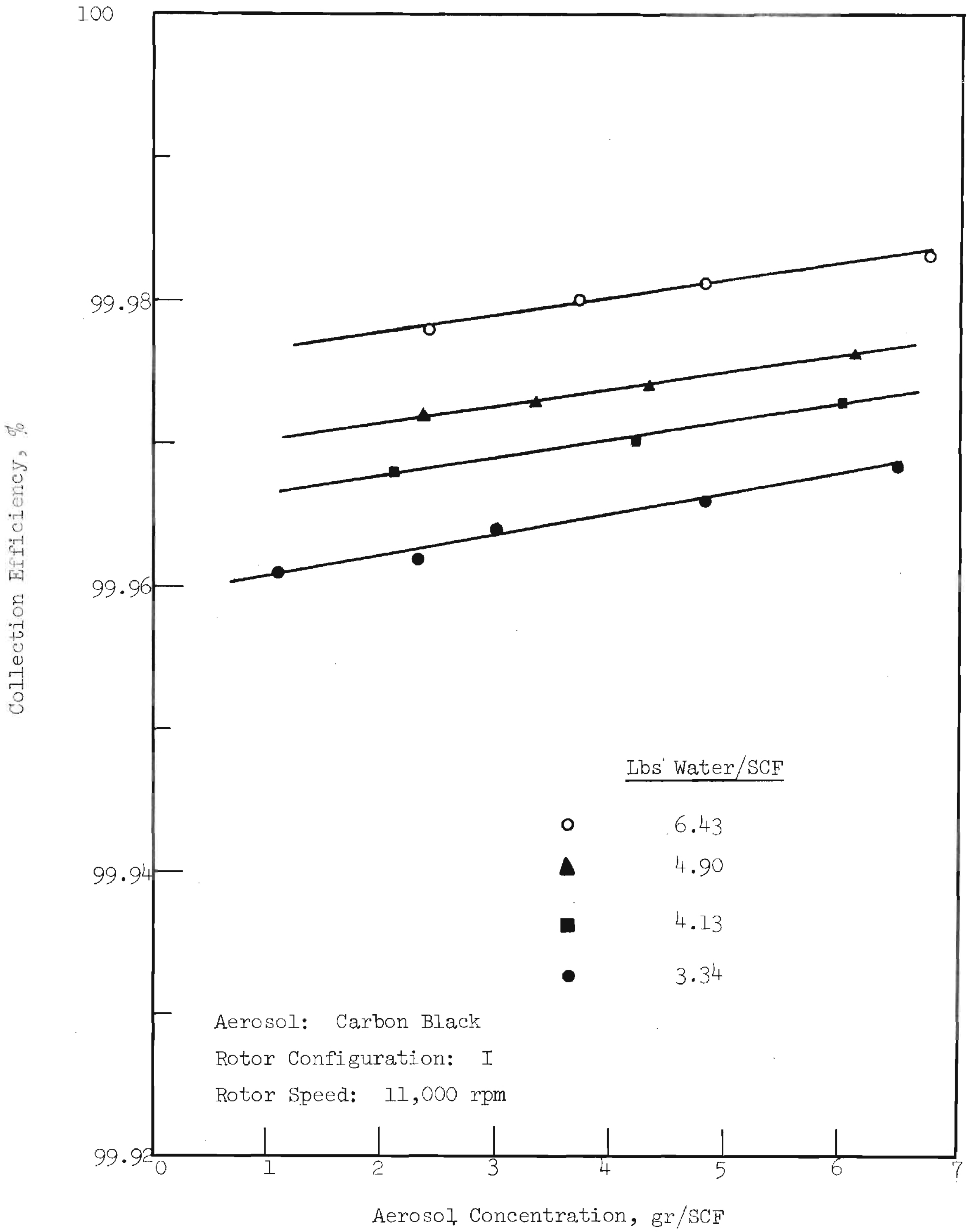


Figure 11. Effect of Aerosol Concentration and Water-Air Ratio on Collection Efficiency in Modified Centrifuge.

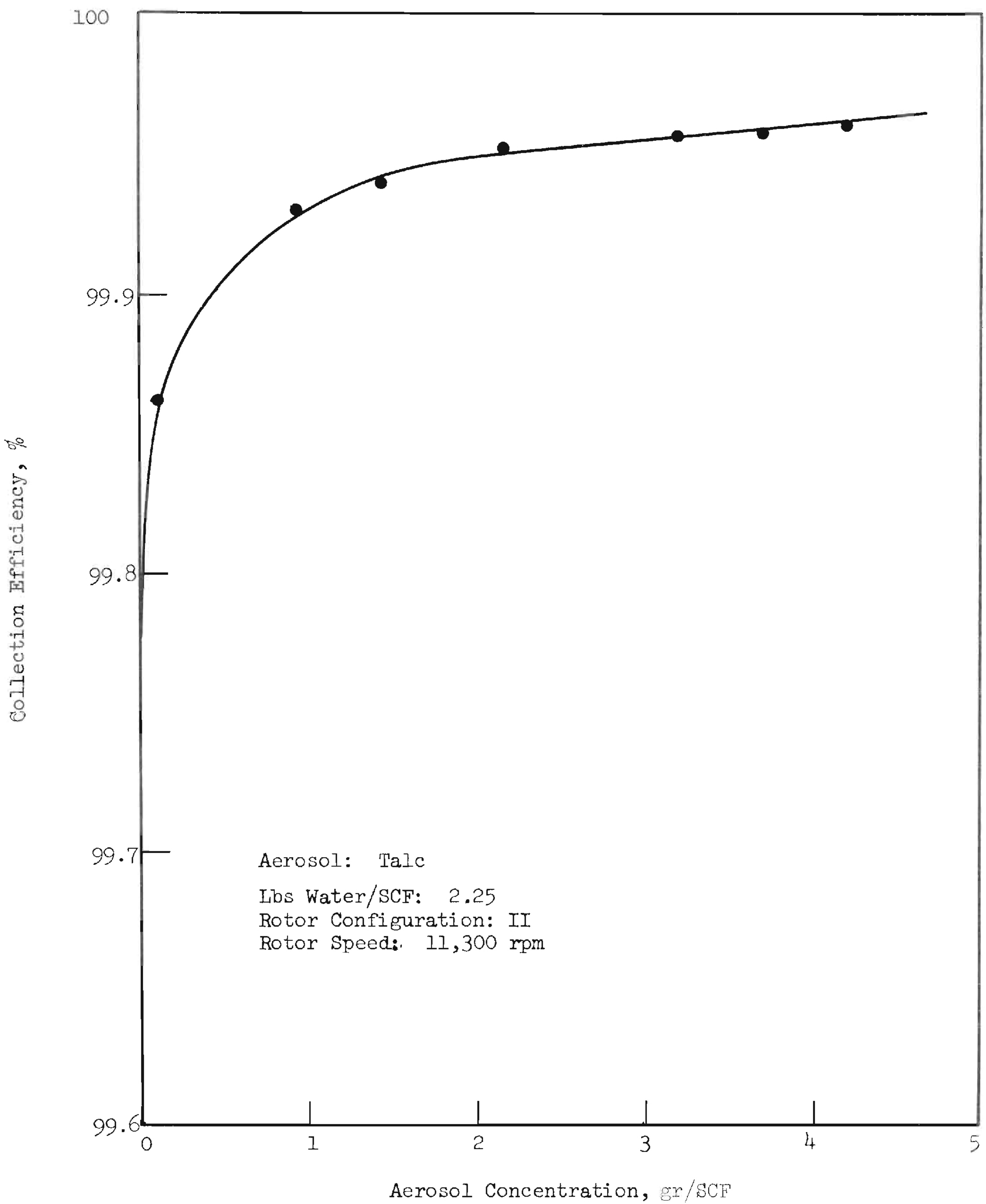


Figure 12. Effect of Aerosol Concentration on Collection Efficiency in Modified Centrifuge.

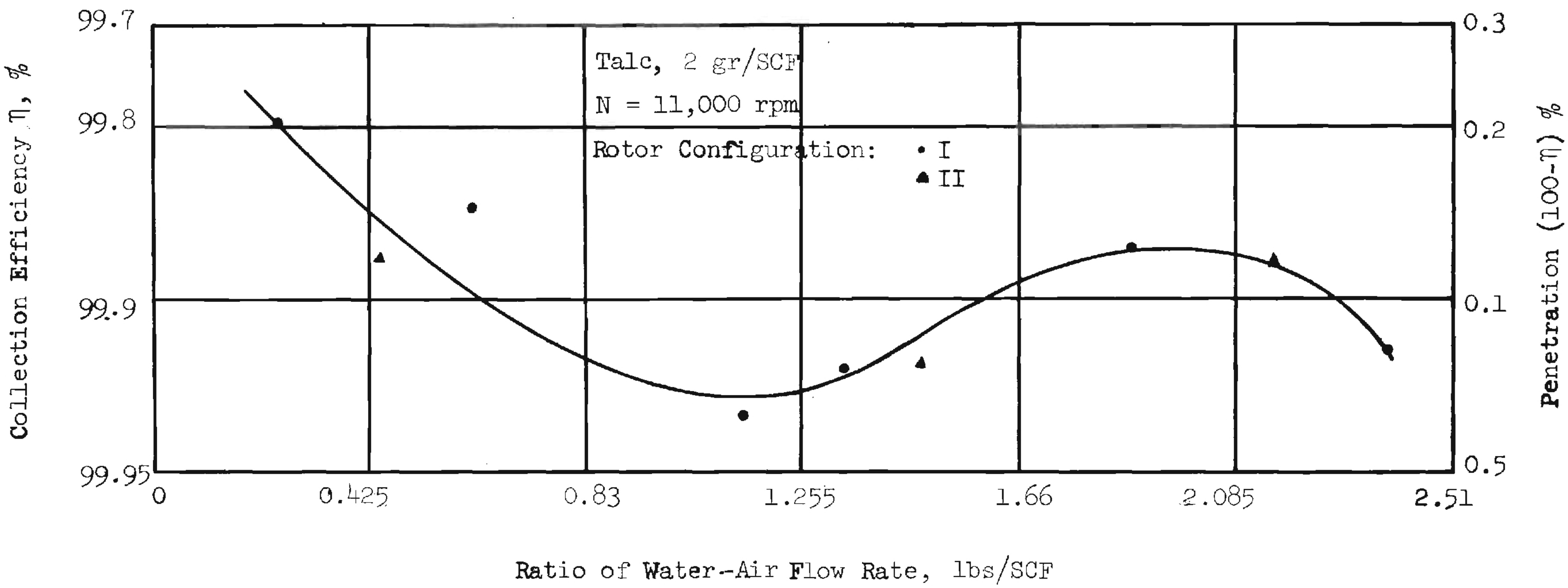


Figure 13. Effect of Water-Air Ratio on Collection Efficiency.

curve are not entirely clear but are probably related to transition from laminar to turbulent flow in the annular region between the rotor and casing. Figure 11 also illustrates the continued increase in collection efficiency as the water-air ratio increases beyond that shown on Figure 13.

4. Effect of rotor speed

Figure 14 shows a relatively rapid increase in collection efficiency for talc aerosols as the rotor speed increases until a speed of about 10,000 rpm is reached and a much slower increase at higher speeds. The logarithmic nature of the relationship between efficiency and rotor speed is shown by Figure 15. The efficiency has been empirically correlated with rotor speed by the expression

$$(100 - \eta) = N^{-\alpha} \tag{3}$$

where η is the mass collection efficiency, N is the rotor speed in rpm, and α is an empirical constant obtained experimentally for each material tested. The empirical constants, α, for alumina, talc, and carbon black were determined experimentally to be 1.5, 2.5, 2.0, respectively.

5. Effect of wetting agents

The principal advantage claimed for the incorporation of surface active agents in water sprays used for the abatement of dust is that they enable the dust to be wet more easily--a factor thought to be advantageous in dust removal. The ability of the surfactant-containing water sprays to wet dust particles more readily is a result of decreased surface tension and decreased interfacial tension between the liquid and solids. Despite the fact that improvements in collection efficiency have previously been

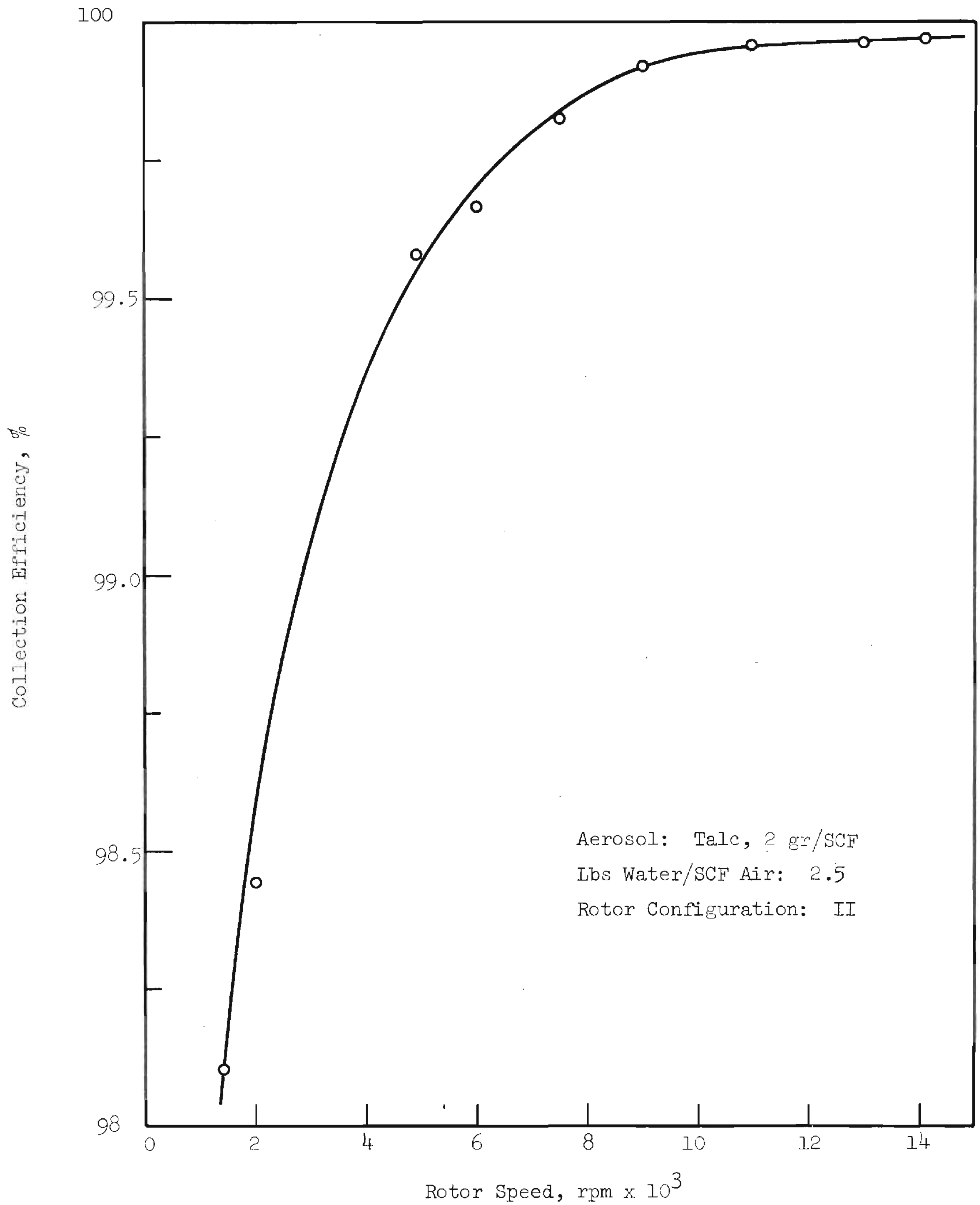


Figure 14. Effect of Rotor Speed on Collection Efficiency.

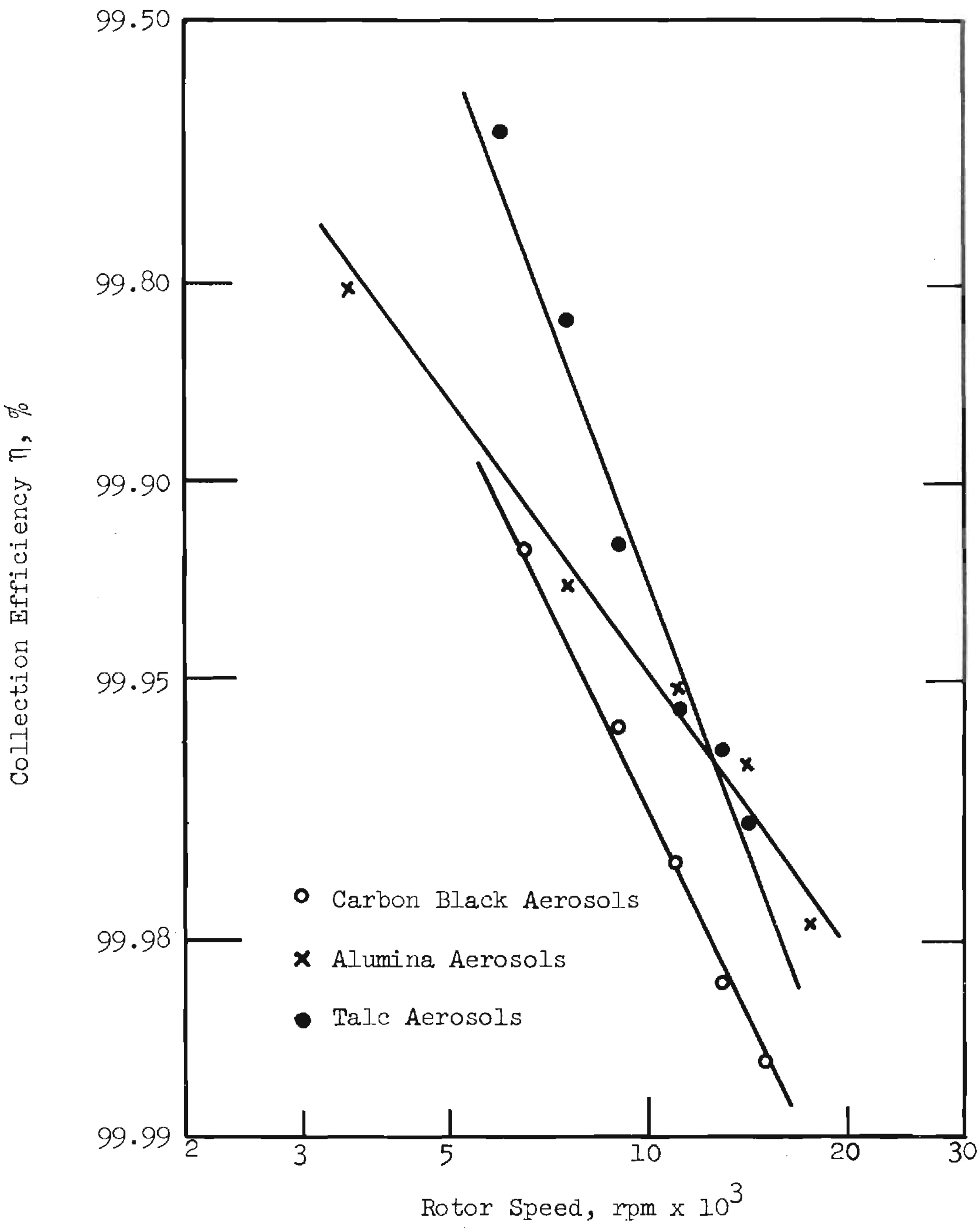


Figure 15. Linear Correlation of Rotor Speeds and Collection Efficiencies.

observed when surfactants were used (7), there is still considerable doubt as to the actual mechanism involved. Walker, et al. (8), concluded that surfactants at the concentrations normally employed in scrubbing operations, had no significant effect on the removal of dusts by inertial impaction methods. A recent study by Drees (9) showed that neutral surfactants did not improve the collection efficiency for quartz particles; however, acidic or basic solutions were found to improve efficiency.

Surfactants may also improve collection efficiency in spray-cleaning devices by improving atomization, and by providing a wetted wall that dust particles can more easily penetrate. Several experiments were conducted both with the laboratory and pilot plant apparatus to evaluate the effectiveness of surfactants.

A slight increase in collection efficiency was noted when the surface tension of the scrubbing liquid was lowered. For these studies, a non-foaming detergent was used as the surfactant and the resulting values of surface tension were determined with a Cenco DuNouy Tensiometer. Figure 16 summarizes the results obtained with the modified centrifuge.

B. Phase II - Simulated industrial stack

1. Effect of particle size on collection efficiency

For typical operating conditions, i.e., an eight-inch diameter rotor

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7/ W. M. Merrits and T. T. Reay, Jr., Bureau of Mines Information Circular 7608 (1951).

8/ P. L. Walker, Jr., E. E. Peterson, and C. C. Wright, "Surface Active Agent Phenomena in Dust Abatement," Ind. and Engr. Chem. 44, No. 10, 2389-2393 (1952).

9/ W. Drees, "Investigation of the Use of Surface Active Substances in Dust Control by Water," Staub (English Translation) 26, No. 12, 31-36 (1966).

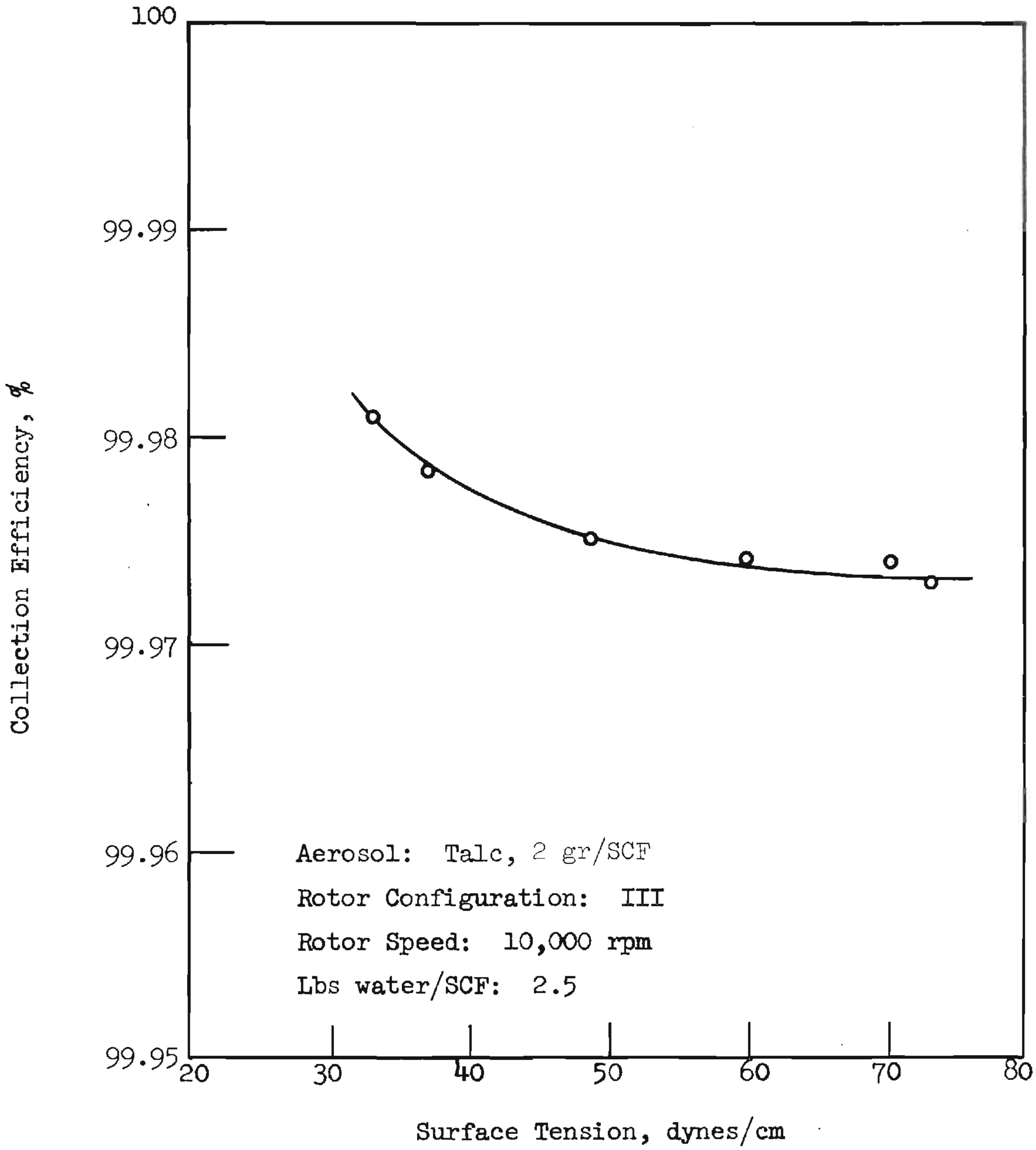

Figure 16. Effect of Surface Tension of Scrubbing Liquid on Collection Efficiency.

turning at 12,000 rpm; a water-air ratio of 0.06 lbs/SCF; and an aerosol concentration of 215 gr/SCF, the removal efficiency was at least 99.9 per cent for alumina powders with particle diameters greater than six microns. Figure 17 illustrates for four different particle size grades of alumina the dependence of collection efficiency on particle size.

2. Effect of aerosol concentration

The simulated stack apparatus was not as sensitive to aerosol concentration as was the modified centrifuge. Grain loadings from approximately 1 to 20 gr/SCF were used and only a slight decrease in efficiencies was observed with concentrations above 15 gr/SCF and below about 2 gr/SCF.

3. Effect of water-air ratio

Much lower water-air ratios were used in the subject scrubber than in conventional designs or in the laboratory model of this study. Figure 18 shows the effect of the water-air ratio for a typical series of test runs.

4. Effect of rotor speed and atomizing surfaces

The most pronounced effect on collection efficiency was due to the rotor speed. Rotor speed versus collection efficiency is shown in Figure 19. Also shown is the average water droplet diameter, as determined from equation (2), for various rotor speeds. The relationship between collection efficiency and the degree of atomization of the scrubbing liquid is clearly seen.

An evaluation was made of the rotor disk when using both surfaces for atomization and when using only one surface. For otherwise fixed conditions, the double atomizing surface showed a marked advantage as is shown by Figure 20. For a fixed water-gas ratio, the double surface allows the water film on the disk to spread thinner with resulting finer atomization.

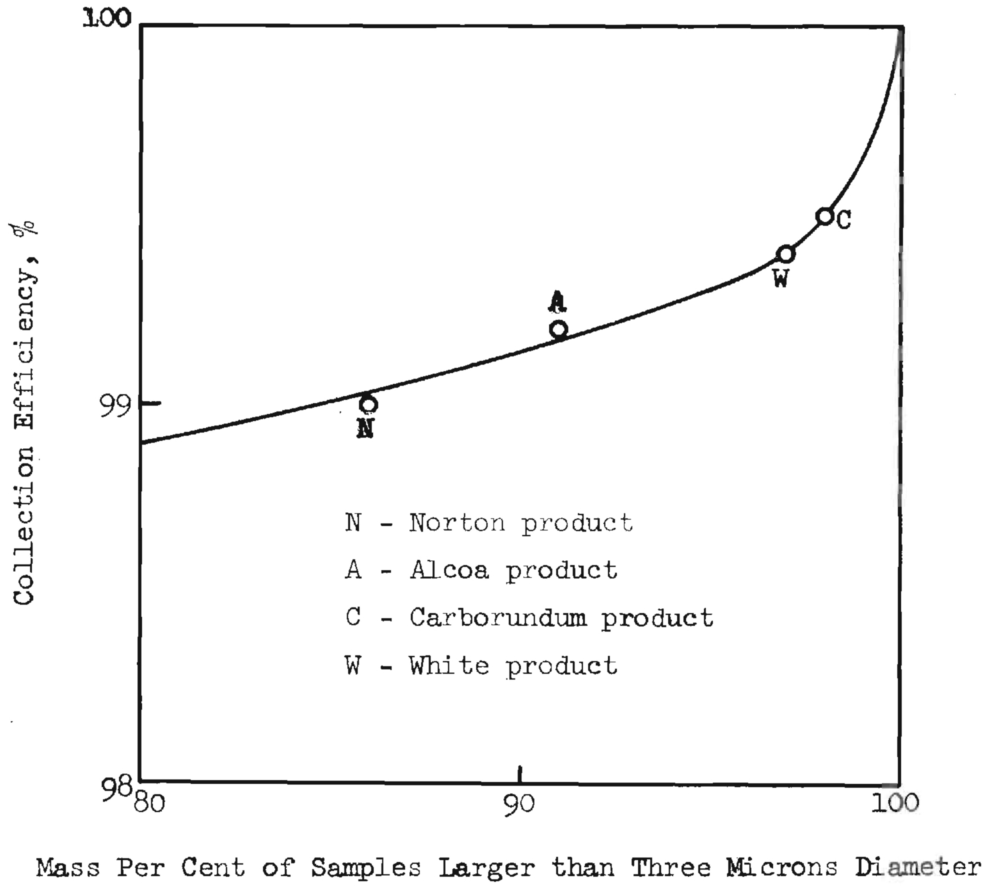

Figure 17. Efficiency of Removal of Aluminum Oxide Particles as a Function of Mass Fraction Larger than Three Microns Diameter.

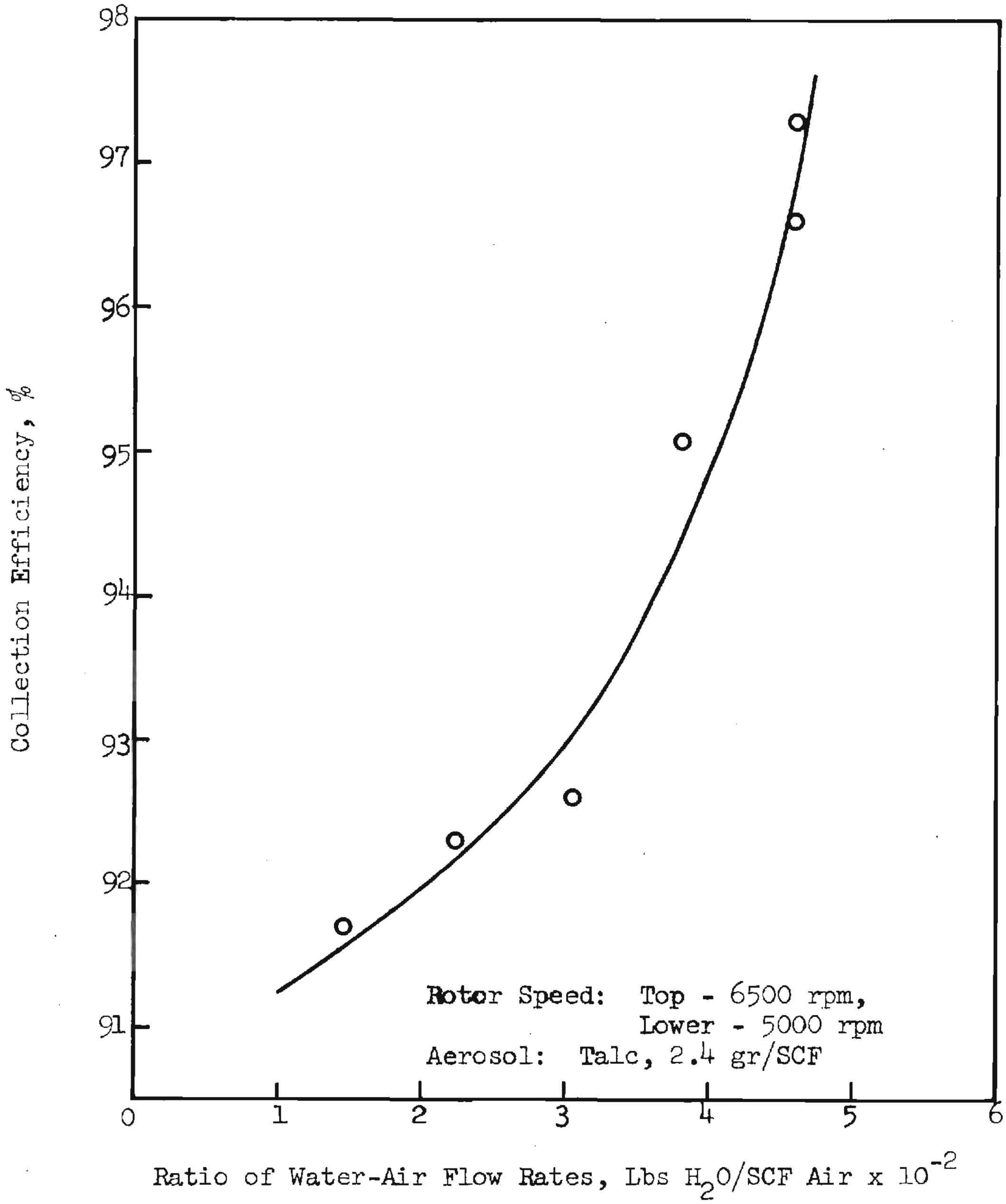

Figure 18. Effect of Water-Air Ratio on Collection Efficiency in Simulated Stack Apparatus.

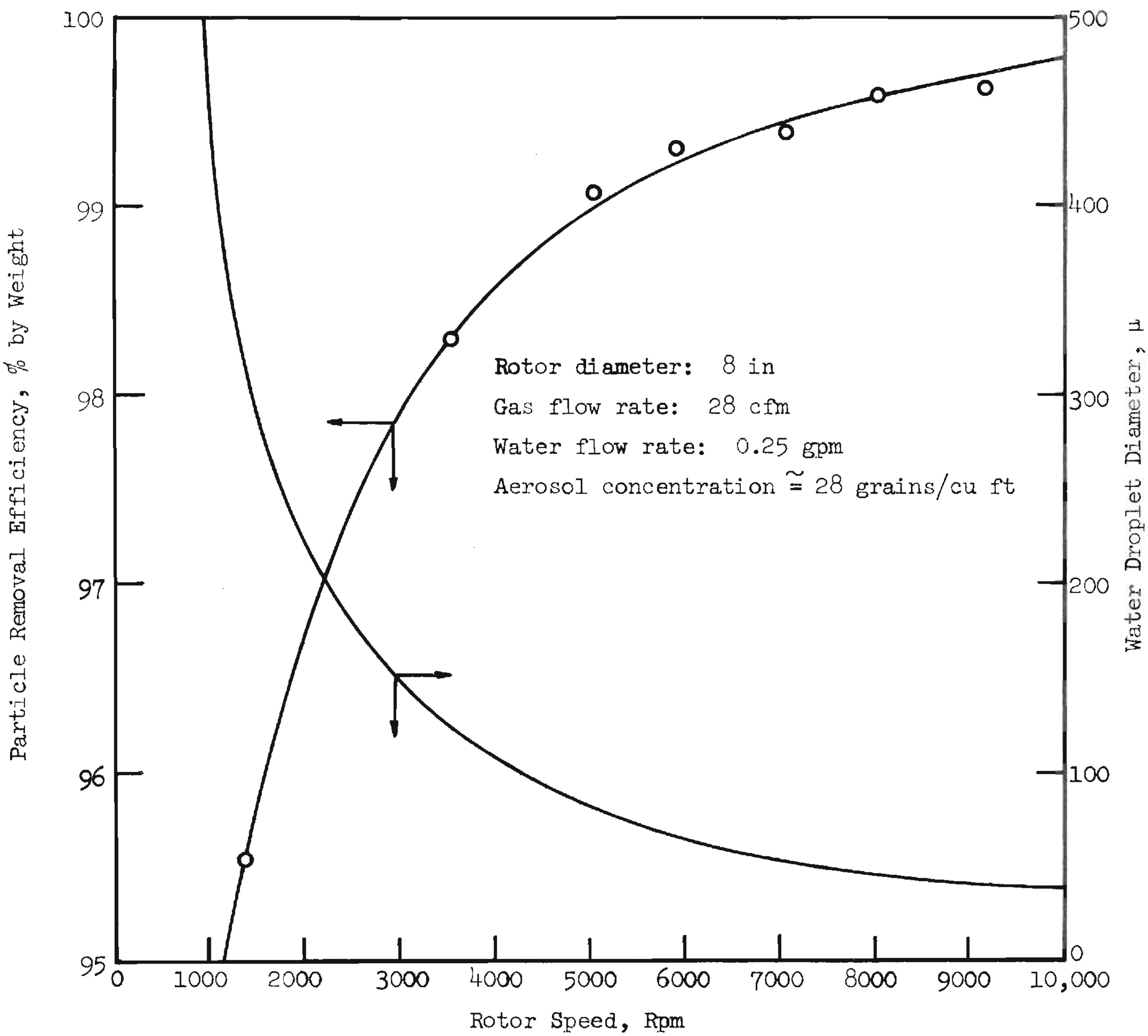

Figure 19. Particle Removal Efficiency Curve for Aluminum Oxide Aerosol (m.m.d. ≅ 8μ)

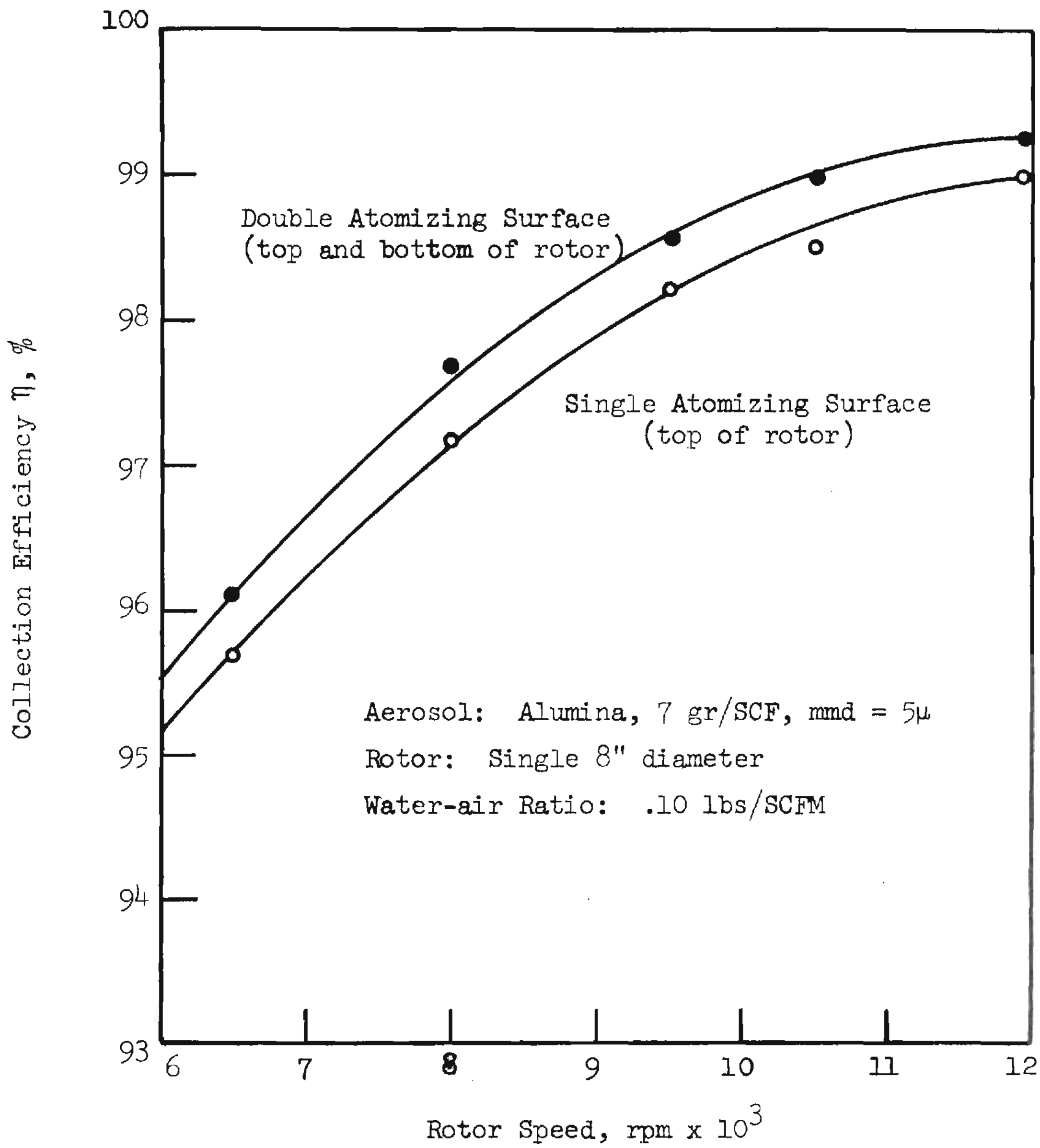

Figure 20. Effect of Atomizing Surface Area and Rotor Speed on Collection Efficiency.

5. Power requirements

The power requirements of a rotating disk atomizer depend primarily on the speed of rotation, the liquid feed rate, and liquid properties. Assuming no slip between the liquid and the disk surface, Marshall and Seltzer (10) obtained a relationship for the net power consumption which was based on the maximum kinetic energy that can be delivered to a liquid leaving a rotating disk. The resulting relationship is

$$P_h = 1.02 \times 10^{-8} \, w \, (Nr)^2 \qquad (4)$$

where P_h is the net horsepower, w is the liquid rate in lbs/min, N is the rotor speed in rpm, and r is disk radius in ft. The total power requirement will be somewhat higher than predicted by equation (4) because of slip at the surface and for various transmission and motor inefficiencies.

To determine the power requirements for this study, input power to the forced draft blowers and the air motors was determined. The input power to the rotors was calculated assuming adiabatic expansion of an ideal gas according to the following relation:

$$w = \frac{NRT_1}{K-1}\left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}}\right] \qquad (5)$$

where w is the input power, R the ideal gas constant, N the moles of gas expanded in the air motors, K the specific heat ratio, which is 1.4 for diatomic gases, T_1 the initial temperature, and P_1 and P_2 the initial and

10/ W. R. Marshall and E. Seltzer, "Principal of Spray Drying," Chem. Eng. Progress 46, 501 (1950).

final pressure, respectively. Figure 21 shows how the total input power per 1000 SCFM gas flow in the simulated stack varied as a function of collection efficiency. The results shown in Figure 21 tend to confirm the Semrau, et al. (11), assertion that collection efficiency is primarily dependent on input power.

6. Pressure drop

The total pressure drop across the 14-foot stack varied from about 1/4 to 1/2 inch, water gage, with a gas flow rate of 500 SCFM and rotor speed of 10,000 rpm.

11/ K. T. Semrau, C. M. Marynowski, K. E. Lunde, and C. E. Lapple, "Influence of Power Input and Efficiency of Dust Scrubbers," Ind. and Eng. Chem. 50, No. 11, 1615-1620 (November 1958).

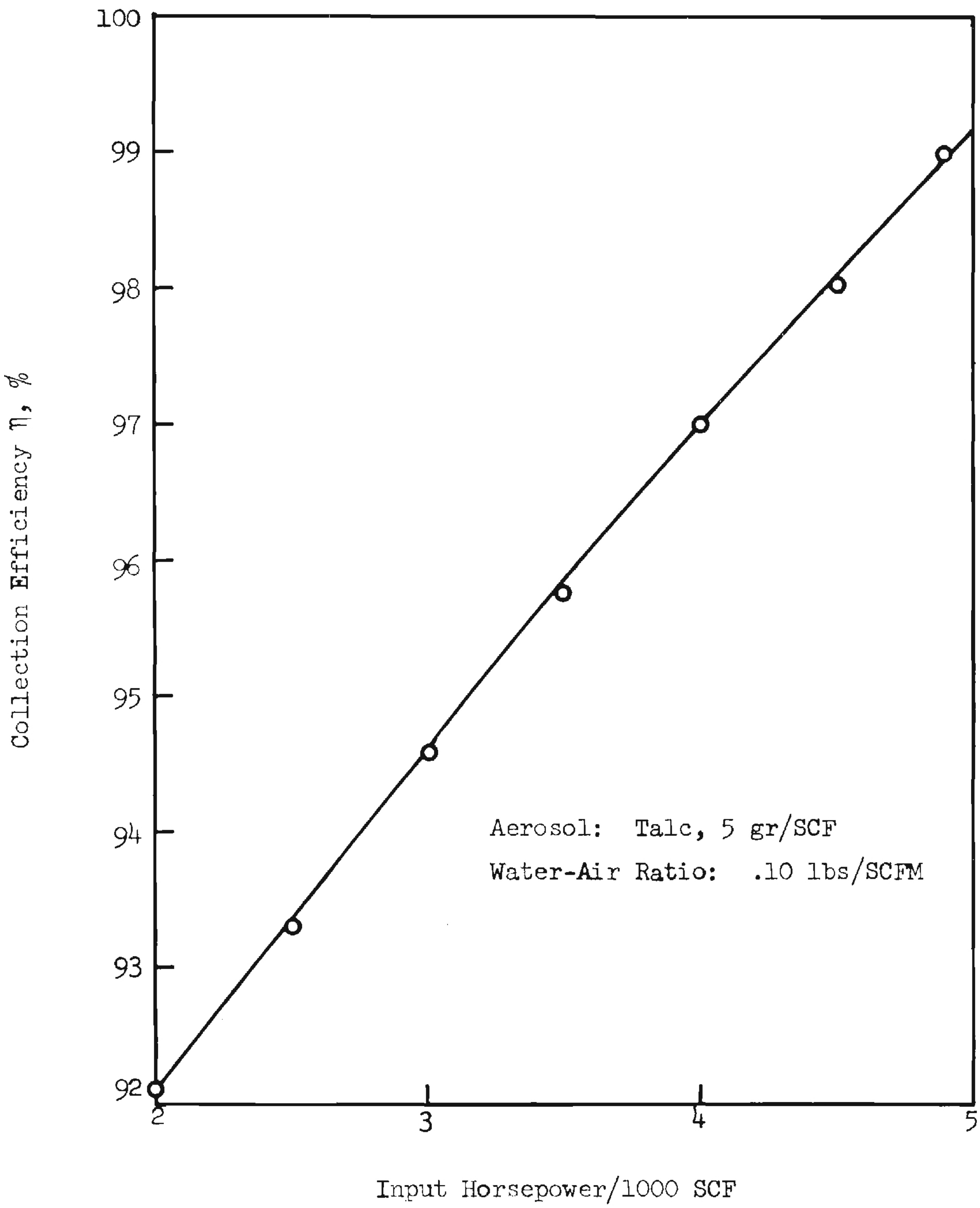

Figure 21. Power Requirements for Simulated Stack Scrubber.

V. CONCLUSIONS AND RECOMMENDATIONS

A wet scrubber which utilizes the combined effects of inertial impaction, centrifugal force, and diffusion has been tested for a wide range of operating conditions and found to be an effective device for removing airborne particulates, especially in the size range below 10 microns diameter. Some of the specific advantages found are:

1. The pressure drop for this device, when operating at 99+ per cent effectiveness, was only one-fourth inch of water. This compares with 20 to 40 inches pressure drop for many venturi-type wet scrubbers.
2. Areas of high erosion are limited to the immediate region of the spinning disk, thereby minimizing the need for large areas of wear-resistant alloys.
3. The water-gas ratios required for high efficiency removal are much lower than for most conventional scrubber designs.
4. The heart of the scrubber is a spinning disk atomizer which might be installed directly in existing stacks or ducts, thereby minimizing the capital expenditure required for effective emission control.

Additional testing work should be accomplished before the full potential of this system can be realized. Some of the major problems and/or questions that remain to be resolved are:

1. The effect of higher speeds for the spinning disks should be thoroughly investigated. The presence of directional vanes, the effects of disk spacing, improved impactor designs, and optimum

spray patterns are some of the major parameters that need additional clarification.

2. One of the limitations of the present design is the carry-over due to entrained water droplets. Cyclone separators and sieve-type demisters should be investigated as possible means of eliminating or minimizing this problem.

3. Large scale pilot plant tests using high gas flow rates, high particle loadings, and high temperatures should be conducted.

4. One of the most attractive features of this system is the potential for effecting simultaneous removal of particulates and gaseous pollutants such as oxides of sulfur. Various scrubbing solutions such as dilute Na_2CO_3 are promising and should be investigated.

Respectfully submitted,

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Approved:

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